

PETROGRAPHY AND CHEMISTRY OF THE MAFIC AND REE-RICH COMPONENTS IN APOLLO SAMPLE 12013. S. N. Valencia, B. L. Jolliff, and R. L. Korotev. Department of Earth and Planetary Sciences, Washington University, St. Louis, Missouri, 63130 (svalencia@levee.wustl.edu).

Introduction: As the only non-mare rock from the Apollo 12 mission, 12013 is unique within the Apollo sample collection [1]. The petrography of 12013 has been studied in detail [e.g. 2,3,4], and early studies characterized 12013 as a dilithologic breccia in that it contains two polymict breccias, a black breccia and a gray breccia, generated by impact [2,4]. Much of the research done on 12013 has been focused on the gray breccia, which is granitic, one of the rarest rock types among lunar samples [4,5]. This work builds on that of [6], which used INAA (instrumental neutron activation analysis) to show that 12013 is best described as a three component system – granitic, mafic and REE-rich (Fig. 1). This work focuses on petrographic descriptions and major mineral chemistry of the mafic and REE-rich end members.

Samples & Methods: Five fragments rich in the mafic component of 12013 (four of 12013,161 and one of 12013,163) and three subsamples containing the REE-rich component (two of 12013,161 and one of 12013,163) were analyzed (Fig. 1). All fragments were previously analyzed by INAA [6]. Polished mounts were then analyzed by EPMA (electron probe micro-analysis). X-ray maps and spot analyses were done on the JEOL JXA-8200 at Washington University in St. Louis with the aim of describing the major & minor element chemistry of the mafic and REE-rich components of the 12013 breccia.

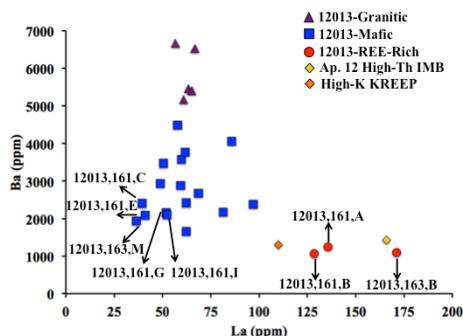


Figure 1. INAA analyses of 12013 fragments. Apollo 12 high-Th IMB (impact melt breccia) and high-K KREEP are also included for reference [7,8]. Labeled samples are those analyzed here. Modified from [6].

Results and Discussion: Sample 12013 is a complex mixture of three components. As such, INAA subsplits can sample more than one component. In order to tease apart these different components, we use EPMA. Fragments used for EPMA are not pure end-member components. For example, granitic material is prevalent in many samples that are also rich in either the mafic or the REE-rich components. In the probe mounts, this granitic material is easily identified; here

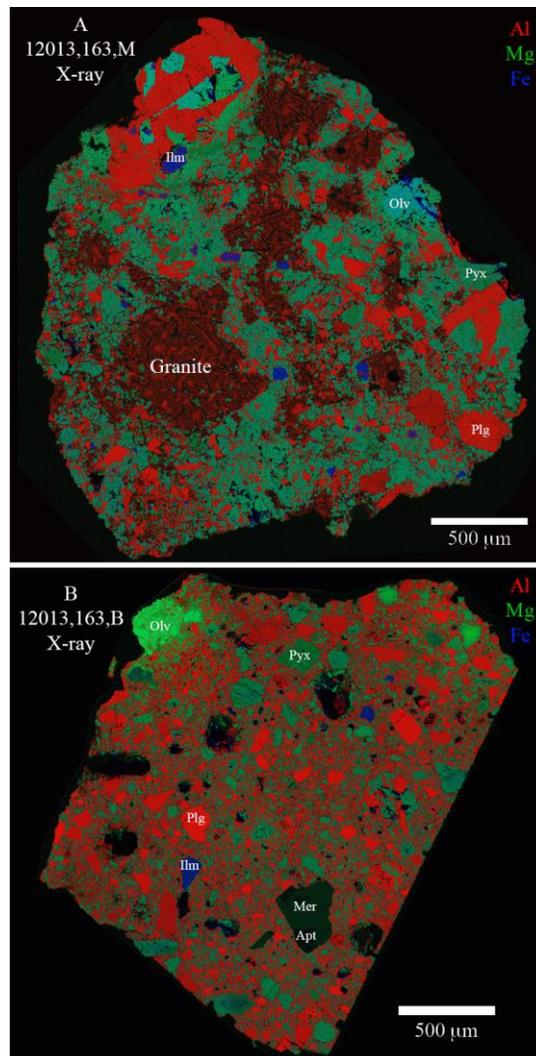


Figure 2. RGB X-ray maps of 12013 fragments. Red: Al, green: Mg, and blue: Fe. Plagioclase (Plg) is bright red, K-feldspar is dark red, pyroxenes (Pyx) are green, olivine (Olv) is bright green or cyan, ilmenite (Ilm) is blue, and REE-minerals (Mer) is dark green. Apatite (Apt) and other minor and trace minerals are black. A. 12013, 163,M, the sample richest in the mafic component of 12013. Dark red regions are granitic. B. 12013,163,B, which has the most REE-rich component.

we focus on the mafic and REE-rich components, which EPMA analyses show vary both in their petrography and mineral chemistry (Fig. 1). Pyroxene and plagioclase compositions for both components are summarized in figure 3.

Mafic Component. Samples of 12013 that contain the greatest proportion of mafic component are dominated by pyroxene including augite, and plagioclase

with a relatively large grain size (Fig. 2A). However, grain size is not uniform within this component. Some portions of the samples have grain sizes less than 10 μm and appear mottled, whereas other portions have a much larger grain size. Some regions of these samples have plagioclase laths up to $\sim 740 \mu\text{m}$ long.

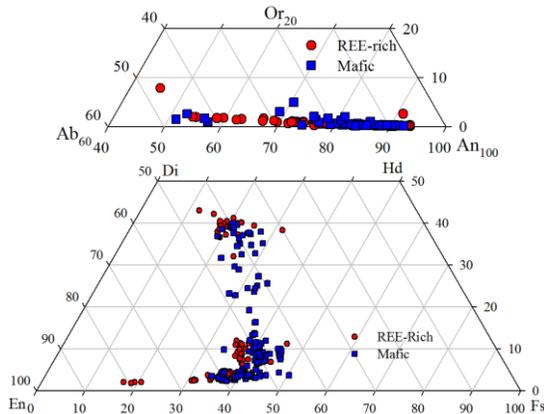


Figure 3. Pyroxene quadrilateral for 12013 samples rich in mafic and REE-rich components.

Pyroxene in the mafic component includes high- and low-Ca pyroxene. Some pyroxene is slightly zoned with Fe-rich rims. Olivine (Fo_{52}) is minor. Other minor and trace minerals include ilmenite, chromite, phosphates, and zircon.

These assemblages are gabbroic (Fig. 2A). The mafic component follows the gabbro trend from the magnesian suite into the alkali suite (Fig. 4). A study of two regions of 12013, 161, E reveal that the mafic component is $\sim 37\text{--}41 \text{ vol.}\%$ plagioclase and $57\text{--}59 \text{ vol.}\%$ pyroxene. A modal recombination of the regions gives bulk FeO concentrations of $\sim 15 \text{ wt}\%$ for the mafic component.

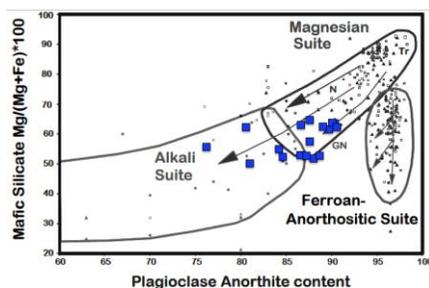


Figure 4. Mg # of mafic silicates vs. An content of coexisting plagioclase for samples rich in the mafic component. Modified from [9].

REE-Rich Component. Grain sizes in the samples dominated by the REE-rich component tend to be smaller than the samples dominated by the mafic component and occur as larger grains (up to $\sim 175 \times 230 \mu\text{m}$) scattered throughout a fine-grained matrix (Fig. 2B).

Pyroxene in the REE-rich component includes both high- and low-Ca pyroxene. Several pyroxenes show

reverse zoning, with cores that are more Fe-rich than their rims. Olivine occurs as a minor mineral, averaging $\sim \text{Fo}_{55}$, except in 12013, 163, B, where olivine is $\sim \text{Fo}_{71}$. Ilmenite, zircon, merrillite, and apatite also occur as coarser grains.

The REE-rich component is dominated by a fine-grained groundmass of plagioclase and pyroxene, along with a host of accessory minerals. This groundmass is relatively homogeneous in grain size and mineralogy throughout the samples. Ilmenite, troilite, K-feldspar, zircon and phosphates make up most of the accessory minerals in the groundmass. Some regions of the groundmass also contain Fe-Ni metal, some of which is S-bearing.

The REE-rich component appears to be an impact melt breccia. Mineral clasts are angular to sub-rounded and occur within a fine-grained matrix. There is porosity (possibly vesicles) in the REE-rich samples, whereas there is little porosity in the other components. Reverse zoning in pyroxene, and varying olivine compositions may indicate that some of the clasts are not in equilibrium with the groundmass. Previous authors noted that the black breccia is a melt-rock, which is consistent with our results [e.g. 2,4].

Although there are compositional similarities between the REE-rich component and the high-Th IMB described by [7], there are important petrographic and chemical differences (Fig. 1). In hand sample, the high-Th IMBs are light colored, whereas the REE-rich fragments in 12013 are black. The fragments with a high amount of the REE-rich component are lower in Th than the high-Th IMBs, but higher in FeO and Sc, indicating that these fragments could be a combination of both high-Th IMB and the mafic component.

Conclusion: The mafic and REE-rich components of 12013 are substantially different in petrography. The mafic component has a coarser grain size than the REE-rich component. The mafic component appears to have a gabbroic protolith whereas the REE-rich component appears to be an impact melt, possibly related to the Apollo 12 high-Th IMBs [7].

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